Using Fuzzy Analytical Hierarchy Process for Multi-criteria Evaluation Model of High-Yield Bonds Investment

Jao-Hong Cheng, Cheng-Wei Chen, and Chen-Yu Lee

Abstract—The returns and risks of High-Yield Bond (HYB) lie between the stocks and Treasury bonds. In view of investment opportunities and the rate of return, the advantages of HYB are both lower risks and higher shares. Therefore, HYB has become one of important components in the portfolios. The purpose of this study is to find evaluation factors and their weights to aid the selection of HYB. The primary criteria to evaluate HYB are established by the literatures survey with Fuzzy Delphi Method (FDM), and then Fuzzy Analytic Hierarchy Process (FAHP) is employed to calculate the weights of these criteria, so as to build the Fuzzy Multi-criteria model of HYB investments. The results indicate a greatest weight on the dimension of economic environment, and three primary evaluation criteria are: (1) spread versus Treasuries, (2) callability, and (3) default rate.

I. INTRODUCTION

Facing the temporarily global decline in economy, the universal interest rates are also in decline, and the outcome is a decline in interest gain as well. In addition, worsened by some non-economic factors, it leads to the stock market plunge in numerous nations. The risk of the stock market has driven the investors to pause and ponder. Hence, for diversification of risks, the portfolio which is able to lead to both acceptable risk tolerance and consistent return becomes the investors’ favor.

While high-yield bond (HYB) continuously grows up in size and expands, the practitioners including the investors, the analysts, and the portfolio managers want to evaluate the risk and the return performance of HYB and use appropriate indicators to effectively select the bonds with worthiness. And the researchers try to figure out the critical factors which can be used to discriminate good bonds from bad ones such that they can objectively evaluate and predict the solvency of individual bonds or bond issuers to raise the rate of return.

In our research, the analysis and integration of theories and studies relative to the HYB selection including HYB evaluation, credit rating model, and evaluation model of financial failure is made, and the collection of variables are divided into four groups which are the characteristics of bonds, corporate non-financial factors, corporate financial factors, and economic environment factors as preliminary evaluation dimensions.

Then two-stage questionnaire investigation is conducted by Fuzzy Delphi Method (FDM) and to select the professionals with the experience of international bonds investment from the trust companies, the bonds agencies, relative divisions of banks, and the stock underwriters to form the experts group as the questionnaire subjects. At first stage, the questionnaire is designed in a fuzzy semantic differential scale, and every expert rates the importance of individual criterion in the form of a triangular fuzzy number and then they reach a consensus in determining the importance to serve as the primary evaluation criteria of HYB investment.

At second stage, the statistic results are provided to these experts and pair-comparison of all criteria is made, then the weight of individual criteria is calculated by Fuzzy Analytic Hierarchy Process (FAHP). Hence, the fuzzy multi-criteria model of HYB investment is established through the process of the experts’ rating the criteria.

II. LITERATURE REVIEW

A. Relative Studies of High-Yield Bonds

High-yield bonds are corporate bonds that have been assigned a bond rating as noninvestment grade by major credit rating agencies such as Moody’s Investors Service, Standard & Poor’s Rating Services, and Fitch Investors Services. The rating agencies analyze the capacity for payment of interest and principal by the issuing organization and the specific issue to determine the credit rating. When the bond issuers are in higher default risk with higher probability of interest payment and principal in arrears, they have to pay the higher rate of interest as a risk premium to attract the investors. Hence, the high-yield bonds are also referred to as speculative bonds and junk bonds.

Hufman and Ward [10] took the default of HYB rated by Moody’s and Standard & Poor’s Corporation as the samples and adopted the Logit regression method in four models to conduct the research. Their results indicate a great correlation between key financial variables and the default of HYB, and growth in assets, change in liquidity, collateralizable assets, and operating profit margin are the important variables in explaining default.

Fabozzi [4] considered the following risks should be taken into account when bonds investment: (1) interest rate risk, (2) reinvestment risk, (3) call risk, (4) default risk, (5) inflation risk, (6) foreign exchange rate risk, (7) liquidity risk, (8) volatility risk, and (9) risk of risk.

Fridson and Garrman [6] studied the determinants of spreads on new HYBs, and they divided the explanatory variables into two groups as company-specific variables and environmental variables. The company-specific variables were credit-risk rating, seniority, term, callability, zero-coupon status, float, 144a status, whether the bond was from a first-time issuer, and the type of underwriter. And the environmental variables included spread versus Treasuries, BB-B spread, yield curve, default rate, volume of initial public offerings, forward calendar, high-yield-bond mutual fund flows, the cash position of high-yield-bond mutual
funds, changes in interest rates, and recent high-yield returns.

Through the above literature survey of HYB evaluation, it provides numerous explanatory variables which are greatly associated with the analysis of HYB evaluation. By integration of these relative literatures, it aims the selection of HYB evaluation variables for this research.

B. Relative Studies of Credit Ratings

Credit rating means the rating of credit status and solvency. The statistical methods are applied to set the rating criteria by quantifying individual credit attributes of the rated objects and calculating their rating grade. And the rating results are provided to the issuers, investors, and stakeholders. Specifically, the purpose of credit rating is to measure the credit risk rather than other investment risks.

The Top-Down approach is adopted in the process of rating by both S&P’s and Moody’s Corporation. For example, the Moody’s Corporation first evaluates the nation risk of the bond issuers to determine their upper bound of the rating grade, and then extends to the industry they belong to whose attributes include industry history, market maturity, business cycle, size, development, competition, and limitation. And the business risk of the bond issuers is measured by both the quantitative and qualitative approaches.

The qualitative analysis focuses on the data of the issuing company itself and the content relative to the issue contract, such as the company’s regulations, past record of interest payment, capability of the authority, the morality, the market share, the position in industry, the impact by business cycle, the industrial perspective, value of the mortgages, and the ways of repayment. As to the quantitative analysis, the issuer’s operational condition and its solvency are introduced, such as asset protection, financial resource, profitability.

The S&P’s Corporation evaluates the ordinary industries by two kinds of risks as business risks (industry properties) and financial risks (financial properties). The business risks include the position of the issuing company (indicators such as market segmentation, technique, and efficiency), administrative capacity, and competitiveness. And the financial risks include financial policy, profitability, capital structure, cash flow, and financial flexibility.

Horrigan [8] applied the Multiple Regression Model to build up the bonds evaluation model, and classified the financial ratios into four groups: long-term and short-term capital turnover, long-term payment ratio, and profitability to serve as the evaluation variables of the enterprise size. The empirical results indicated an accuracy rate of 58% at the prediction of Moody’s credit ratings while an accuracy rate of 52% at the prediction of S&P’s credit ratings.

Pinches & Mingo [15] employed the factor analysis to introduce seven factors which were earnings stability, company size, financial leverage, long-term capital intensity, rate of returns, debt stability, and short-term capital intensity into the discrimination model. The results presented an accuracy rate of 69.7% for original samples and an accuracy rate of 64.58% for validation samples.

Goh & Ederington [7] explored the reaction of stock market on the change duration of bonds upgrading and downgrading. The results proved a correlation between stock market and ratings change, that is, a stronger impact on the stock market by the magnitude of downgrading at low-ratings than at high-ratings.

C. Relative Studies of Financial Failure

Since Beaver [2] had initiated the prediction of financial failure by the financial ratios, many scholars made their efforts to study the prediction model of financial failure in order to find out a fitter model to predict financial failure. Ohlson [14] analyzed the properties of 105 bankrupt companies by the dimensions of financial ratios, company size, financial structure, operational performance, and liquidity.

Flagg et al. [5] used four potential failure “events”: reductions in dividends, “going concern” qualified opinions, troubled debt restructurings, and violations of debt covenants. In addition, six financial ratios were included in the model: current ratio, cash flows to total assets, total debt to total assets, net earnings to total assets, retained earnings to total assets, and log of total assets. The results suggested two events (reductions in dividends and “going concern” qualified opinions) and four ratios (current ratio, total debt to total assets, net earnings to total assets, retained earnings to total assets) were significant factors.

D. Relative Studies of Fuzzy Delphi Method and Fuzzy Analytic Hierarchy Process

Delphi is a technique for structuring an effective group communication process by providing feedback of individual contributions of information and assessment of the group judgment, and enabling individuals to re-evaluate their judgments. Since its development in the 1960s at Rand Corporation, the Delphi method has been widely used as a forecasting technique. In order to solve the problem of traditional Delphi method, Ishikawa et al. [12] introduced the fuzzy theory into the Delphi method to improve time-consuming problems from Hwang and Lin [11] such as the convergence of experts’ options.

The analytic hierarchy process (AHP) methodology was developed by Satty [18]. It is a powerful method in solving complex decision problems. The AHP helps the analysts to organize the critical aspects of a problem into a hierarchical structure similar to a family tree. By reducing complex decisions to a series of simple pairwise comparisons and rankings, then synthesizing the results, the AHP not only helps the analysts to arrive at the best decision, but also provides a clear rationale for the choices made.

Hence, AHP approach has been widely applied in various relative fields to solve the decision-making problems with multiple hierarchies under the situation of uncertainty. Besides, due to the defect of traditional AHP application by Buckley [3] such as the characteristics of subjectiveness, fuzziness, and imprecision, many researchers such as Ruining and Xiaoyan [17] incorporated the Fuzzy theory into the AHP method to improve its application.

In this study, due to the fuzziness existed in the part of evaluation criteria, we decide to adopt the Fuzzy Delphi
Method (FDM) to form the primary evaluation criteria of HYB selection, and employ the Fuzzy Analytic Hierarchy Process (FAHP) to calculate the weight of individual criteria so as to establish the Fuzzy Multi-criteria Model of high-yield bonds (HYB) selection. Relative to the selection of variables, Altman [1] selected the variables according to (1) Adopted by general literatures, (2) Variables related to the purpose of the conducted study. Successive researches mostly followed Altman’s rules.

Our research also refers to these rules and combines two methodologies. The evaluation factors directly related to our study’s purpose are included through the survey of relative literatures about high-yield bonds investment. Then we compare the above selected factors with the evaluation factors of relative studies of credit ratings and financial failures respectively in pairs to obtain the factors with significant importance.

III. THE METHODOLOGY AND THE ANALYSIS OF RESULTS

A. Choosing the Experts

This study focuses on the analysis of evaluation criteria of HYB selection. Thus the experts chosen are the professionals in the fields related to our research with the experience of international bonds investment from the trust companies, the bonds agencies, relative divisions of banks, and the stock underwriters. Besides, they should have at least 5 years of working experience with the market investment experience, and their positions are at least the rank of assistant managers. Robbins [16] considered the number of experts between 5 and 7, and therefore we select seven experts. Moreover, in order to reach the consistency in data collection, the identical experts group is adopted at both first stage and second stage as the questionnaire subjects.

B. Determining the Evaluation Criteria

The Fuzzy Delphi Method is employed to explore the important criteria of HYB selection, and there are the following steps:

Step 1. Building the Evaluation Criteria

At first stage, through the literature survey of high-yield bonds, credit ratings, and prediction model of financial failures, we obtain important variables such as “the characteristics of bonds”, “corporate non-financial factors”, “corporate financial factors”, and “economic environment factors”. And these variables are organized as dimensions.

At this stage, five bond characteristics, six corporate non-financial factors, 25 financial ratios, and 11 economic environment factors are totally chosen, and the financial ratios are further classified into six categories according to the classification of domestic Prospectus as solvency, operational effectiveness, analysis of profitability, financial structure, growth potential, and cash flow.

Step 2. Collecting the Experts’ Opinions

The selected experts are asked to answer the questionnaire in a 9-point fuzzy semantic differential scale of “absolutely important”, “very important”, “pretty important”, “quite important”, “no comment”, “fairly unimportant”, “quite unimportant”, “very unimportant”, and “absolutely unimportant”. And the experts assign a relative importance to individual criteria with respect to four dimensions of bonds’ characteristics, corporate non-financial and financial factors, and economic environment factors in order to form the important criteria of HYB selection.

Step 3. Applying the Fuzzy Delphi Method to Select the Evaluation Criteria

(i) Establishing the Triangular Fuzzy Function

The experts’ estimations gathered by prior step are used to establish the triangular fuzzy function of individual criteria through the process of Fuzzy Delphi Method by Ishikawa et al. [12]. The process of application is as follows:

1. The elements of evaluation set are determined by the experts’ questionnaires of high-yield bonds selection. Given a score of 100 and 0 to the traditional binary logics of “absolutely important” and “absolutely unimportant” respectively, the other elements of evaluation set are quantified objectively through the treatment of Fuzzy Delphi Method.

2. The questionnaires are designed for the elements of set other than “absolutely important” and “absolutely unimportant”, and the experts are invited to fill the quantitative score interval of individual elements in the evaluation set. The maximum of interval value is the experts’ most optimistic cognition of the quantitative score for the element, and the minimum of interval value is the experts’ most conservative cognition of the quantitative score for the element.

3. Solving the minimum L, geometric mean M, and the maximum U of all experts’ most optimistic recognition score for individual elements, along with the minimum l, geometric mean m, and the maximum u of all experts’ most conservative cognition score for individual elements, respectively.

Triangular fuzzy number \( A = (L, M, U) \) of all experts’ most optimistic cognition for individual elements and triangular fuzzy number \( a = (l, m, u) \) of all experts’ most conservative cognition for individual elements are established, respectively. It is shown as Figure 1.

![Triangular fuzzy number](image)

Fig. 1. Triangular fuzzy number of the most optimistic cognition and the most conservative cognition

(ii) Analyzing the Value of Triangular Fuzzy Function

To organize and analyze the experts questionnaire collected at first stage, triangular fuzzy function with respect to individual evaluation criteria is established as shown in Table 1.
(iii) Selecting the Evaluation Criteria

When selecting the evaluation criteria, it is generally considered important if the importance is greater than 80%. Hence, we assign the score of more than 80 to the median of gray interval as threshold, and the important criteria consistently agreed by those experts are accordingly selected.

Obtained from the collected experts’ questionnaires, there are 17 important criteria commonly agreed by 7 experts. They are listed as follows.

1. The characteristics of bonds: (1) bond liquidity, (2) change in credit rating, and (3) bond callability

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Evaluation Criteria</th>
<th>The Most Conservative Cognition (min, median, max)</th>
<th>Gray Interval</th>
<th>The Most Optimistic Cognition (min, median, max)</th>
<th>The Median in Gray Interval</th>
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<td>Characteristics of Bonds</td>
<td>Liquidity</td>
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<td>(92,80)</td>
<td>(80,92,09,100)</td>
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<td></td>
<td>Duration</td>
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<td>(85,70)</td>
<td>(70,80,05,92)</td>
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<td>Change in Credit Rating</td>
<td>(71,81,83,92)</td>
<td>(92,80)</td>
<td>(80,92,09,100)</td>
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<td>Callability</td>
<td>(68,84,68,92)</td>
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<td>(81,95,87,100)</td>
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<td>Maturity</td>
<td>(55,65,23,85)</td>
<td>(85,68)</td>
<td>(68,75,68,92)</td>
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<td>Non-financial Factors</td>
<td>Company Size</td>
<td>(55,65,04,85)</td>
<td>(85,65)</td>
<td>(65,75,92)</td>
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<td>Mortgage Assets</td>
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<td>(60,78,92)</td>
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<td>Volatility of Current Assets</td>
<td>(48,71,72,85)</td>
<td>(85,62)</td>
<td>(62,81,95,92)</td>
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<td>Operating Profit Margin</td>
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<td>(70,85,97,100)</td>
<td>77.5</td>
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<td>Issuer or Administrator</td>
<td>(45,68,85)</td>
<td>(85,55)</td>
<td>(55,78,54,92)</td>
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<td>Company Seniority</td>
<td>(45,55,61,71)</td>
<td>(71,55)</td>
<td>(55,67,25,83)</td>
<td>63</td>
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<td>Solvency</td>
<td>Current Ratio</td>
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<td>(92,80)</td>
<td>(80,90,17,100)</td>
<td>86</td>
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<td>Quick Ratio</td>
<td>(69,78,37,92)</td>
<td>(92,80)</td>
<td>(80,87,99,100)</td>
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<td>Operating Capital Ratio</td>
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<td>(70,82,42,92)</td>
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<td>Interest Expense Rate</td>
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<td>(80,80)</td>
<td>(80,85,62,92)</td>
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<td>Receivables Turnover</td>
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<td>(85,65)</td>
<td>(65,82,73,92)</td>
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<td>Fixed Assets Turnover</td>
<td>(55,66,45,80)</td>
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<td>(65,77,26,90)</td>
<td>72.5</td>
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<td>Total Assets Turnover</td>
<td>(55,66,45,80)</td>
<td>(80,65)</td>
<td>(65,77,26,90)</td>
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<td>Analysis of Operating Efficiency</td>
<td>Equity Turnover</td>
<td>(55,68,50,80)</td>
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<td>(65,79,35,90)</td>
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<td>Analysis of Profitability</td>
<td>Gross Profit Margin</td>
<td>(55,64,41,81)</td>
<td>(81,65)</td>
<td>(65,74,89,90)</td>
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<td>Operating Profit Margin</td>
<td>(60,71,20,81)</td>
<td>(81,70)</td>
<td>(70,82,82,92)</td>
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<td>Earning before Tax Margin</td>
<td>(68,73,59,81)</td>
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<td>(81,84,90,90)</td>
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<td>Net Profit Margin</td>
<td>(69,74,39,82)</td>
<td>(82,81)</td>
<td>(81,86,71,90)</td>
<td>81.5</td>
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<td></td>
<td>Return on Equity</td>
<td>(61,68,18,82)</td>
<td>(82,70)</td>
<td>(70,78,06,90)</td>
<td>76</td>
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<td></td>
<td>Return on Total Capital</td>
<td>(61,67,70,71)</td>
<td>(71,70)</td>
<td>(70,78,86,83)</td>
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<td>Return on Net Worth</td>
<td>(68,73,43,81)</td>
<td>(81,80)</td>
<td>(80,85,06,92)</td>
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<td>Financial Structure</td>
<td>Current Assets / Total Assets Ratio</td>
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<td>(85,80)</td>
<td>(80,82,68,92)</td>
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<td>Retained Earnings / Total Assets Ratio</td>
<td>(61,73,07,92)</td>
<td>(92,70)</td>
<td>(75,83,96,100)</td>
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<td>Debt Ratio</td>
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<td>(81,90,00,100)</td>
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<td>ROE / Debts Ratio</td>
<td>(55,75,82,92)</td>
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<td>(65,86,12,100)</td>
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<td>Fixed Assets Ratio</td>
<td>(55,68,89,85)</td>
<td>(85,65)</td>
<td>(65,78,87,92)</td>
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<td>Analysis of Growth</td>
<td>Assets Growth</td>
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<td>Net Income (NI)</td>
<td>(55,69,60,85)</td>
<td>(85,65)</td>
<td>(65,78,67,92)</td>
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<td>Cash Flow / Total Debts Ratio</td>
<td>(68,79,16,92)</td>
<td>(92,80)</td>
<td>(80,90,17,100)</td>
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<td>Cash Flow / Sales Ratio</td>
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<td>(65,82,16,100)</td>
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<td>Cash Flow / Total Assets Ratio</td>
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<td>(92,65)</td>
<td>(65,78,33,100)</td>
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<td>Economic Environmental Factors</td>
<td>Default Rate Index</td>
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<td>(92,70)</td>
<td>(70,85,75,100)</td>
<td>81</td>
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<td>Inflation Rate</td>
<td>(60,72,82)</td>
<td>(82,70)</td>
<td>(70,82,62,92)</td>
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<td>Leading Index</td>
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<td>(85,55)</td>
<td>(55,79,44,100)</td>
<td>70</td>
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<td>Mutual Fund Flow</td>
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<td>(68,55)</td>
<td>(55,67,86,81)</td>
<td>61.5</td>
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<td>GDP</td>
<td>(40,60,05,78)</td>
<td>(78,54)</td>
<td>(54,72,30,92)</td>
<td>66</td>
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<td>Stock Index</td>
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<td>(82,45)</td>
<td>(45,67,74,90)</td>
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<td>Real Interest Rate Change</td>
<td>(70,79,67,85)</td>
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<td>(80,86,62,92)</td>
<td>82.5</td>
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<td></td>
<td>January Effect</td>
<td>(18,44,28,61)</td>
<td>(61,40)</td>
<td>(40,60,13,70)</td>
<td>50.5</td>
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<td>Zero Coupon Status</td>
<td>(47,59,97,82)</td>
<td>(82,59)</td>
<td>(59,70,09,90)</td>
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<td></td>
<td>BB-B Spreads</td>
<td>(45,67,33,91)</td>
<td>(91,55)</td>
<td>(55,78,28,100)</td>
<td>73</td>
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<td></td>
<td>Spreads versus Treasury</td>
<td>(69,75,59,91)</td>
<td>(91,80)</td>
<td>(80,86,49,100)</td>
<td>85.5</td>
</tr>
</tbody>
</table>
2. Financial factors: (1) solvency: a. current ratio, b. quick ratio, and c. Interest expense rate, (2) analysis of profitability: a. pre-tax profit margin, b. net profit margin, and c. return on assets, (3) financial structure: a. current assets / total assets ratio, b. retained earnings / total assets ratio, and c. debt ratio, (4) analysis of growth: a. assets growth rate, and (5) cash flow: a. cash flow / debts ratio

3. Economic environmental factors: (1) default rate index, (2) real interest rate change, and (3) spreads versus Treasury.

C. Applying the Fuzzy Analytic Hierarchy Process

In this section, we apply the fuzzy analytic hierarchy process (FAHP) to calculate the weights of individual dimension and individual criteria of HYB selection. The process is listed as follows.

Step 1. Building the Hierarchical Structure

The first is to build the hierarchical structure. The goal is placed at the top of hierarchy, and the general criteria (dimensions) are placed at second level. The secondary subcriteria with respect to each dimension are placed at third level, and the tertiary subcriteria with respect to each secondary subcriteria are placed at the fourth level.

In our case, the goal at the top level is “evaluation of HYB selection”, and there are three evaluation dimensions of “the characteristics of bonds”, “financial factors”, and “economic environmental factors” at second level. With respect to each dimension at second level, there are some secondary subcriteria listed at third level. For example, there are five secondary subcriteria: “solvency”, “profitability”, “financial structure”, “growth”, and “cash flow” with respect to the dimension “financial factors”.

Moreover, there are several tertiary subcriteria with respect to each secondary subcriteria, such as “current ratio”, “quick ratio”, and “interest expense rate” with respect to “solvency”. The detail of hierarchical structure is shown as Figure 2.

Step 2. Building the Pairwise Comparison Matrix

By the second questionnaires collected from experts, we obtain the relative importance of paired factors at level n+1 under the evaluation of criteria at level n by individual experts’ opinions, and the pairwise comparison matrix is accordingly formed.

Step 3. Building Triangular Fuzzy Numbers

Concerning the relative importance of individual evaluation criteria in pairwise comparison matrix, triangular fuzzy number is adopted to integrate all experts’ opinions. This could adequately present the fuzziness of all experts’ opinions with respect to the relative importance of paired factors.

\[ a_{ij} = (\alpha_{ij}, \beta_{ij}, \delta_{ij}) \]_{i \leq j}

Where

- \( a_{ij} \): Triangular fuzzy number
- \( \alpha_{ij} \): The minimum of the j-th subcriteria subordinated to the i-th general criteria
- \( \beta_{ij} \): The geometric mean of the j-th subcriteria subordinated to the i-th general criteria
- \( \delta_{ij} \): The maximum of the j-th subcriteria subordinated to the i-th general criteria
Step 4. Building the Fuzzy Positive Reciprocal Matrix

After the triangular fuzzy numbers are solved to represent the fuzziness of experts’ opinions, the fuzzy positive reciprocal matrix A can be further built.

\[ A = \left[ \begin{array}{ccc}
\alpha_{11} & \beta_{11} & \delta_{11} \\
\alpha_{21} & \beta_{21} & \delta_{21} \\
\end{array} \right] \]

Step 5. Calculating the Fuzzy Weights of Fuzzy Positive Reciprocal Matrix

In our study, we employ the method which is developed by Buckley [3] and improved by Hsu [9] to calculate the fuzzy weights. This method is based on the experts’ precise value and synthesizes the experts’ opinions with the geometric mean instead of the fuzzy numbers input directly by experts. Thus, not only the consistency but also the concept of normalization is easily achieved. Through the following formulas, the positive reciprocal geometric mean \( Z_i \) and the fuzzy weight \( \tilde{W_i} \) can be obtained.

\[ Z_i = \left[ \alpha_i \otimes \beta_i \otimes \delta_i \right]^{1/n}, \forall i, \]

\[ \tilde{W_i} = Z_i / \left( Z_1 \otimes Z_2 \otimes \ldots \otimes Z_m \right)^{1/n} \]

Where \( Z_i \) is the geometric mean of triangular fuzzy numbers

\[ \tilde{a}_i = (\alpha_i, \beta_i, \delta_i) \]

\[ \tilde{a}_i = (\alpha_i + \beta_i, \beta_i + \delta_i, \delta_i + \alpha_i) \]

\[ Z_i = \left[ \alpha_i, \beta_i, \delta_i \right]^{1/n} \]

\[ \tilde{a}_i = \left[ \alpha_i^{1/n}, \beta_i^{1/n}, \delta_i^{1/n} \right] \]

Step 6. Defuzzification

Since the weights of individual dimensions and criteria are fuzzy values, it is necessary to solve a nonfuzzy value by the process of defuzzification. In our study, the Centroid method is employed to defuzzify, and the reasons are: (1) the Centroid method is widely used in relative literatures as Klir’s and Yuan’s [13], and (2) the solution can be figured out quite quickly. Through the following formulas, the defuzzified weight \( W_i \) can be obtained.

\[ W_i = \frac{W_a + W_b + W_d}{3} \]

\( W_a \): The right-end value of the fuzzy weight

\( W_b \): The fuzzy weight’s value with the degree of membership as 1

\( W_d \): The left-end value of the fuzzy weight

Step 7. Normalization

In order to effectively compare the importance among various dimensions and criteria, we normalize the obtained weights as follows.

\[ NW_i = \frac{W_i}{\sum W_i} \]

Step 8. Syntheses of Hierarchy

The weights of individual dimensions (criteria) and subcriteria can be obtained by step 1 through step 7. If the weights of criteria or subcriteria at upper hierarchy need to be calculated, then the weights of their subordinated subcriteria should be synthesized. By the following formula, the synthesizes of weights at various level of hierarchy can be obtained.

\[ NW_i = NW_i \times NW_{ip} \]

D. The Empirical Results

In this research, we apply the Fuzzy Analytic Hierarchy Process (FAHP) method to calculate the relative importance among individual dimensions and subcriteria on the evaluation of HYB selection, and the empirical results such as the weights and the ranks of individual criteria or subcriteria are also presented in Figure 2. Where the obtained weights are the decimals below individual criteria or subcriteria, and the ranks of individual lowest subcriteria are the numbers in parentheses below the weights. Accordingly, the further explanations are as follows.

1) Comparison of weights among dimensions

Concerning four dimensions related to the investment of high-yield bonds, there is a greatest weight of 0.4044 on the dimension “economic environmental factors”, and the second is the dimension “characteristics of bonds” of 0.3521. The third is the dimension “financial factors” of 0.2436, whereas the dimension “nonfinancial factors” is excluded.

The above results indicate that the experts generally consider the dimension “economic environmental factors” a greatest impact on selection of high-yield bonds, and the reason is that the default rate index and return are important indicators to influence the investment. Moreover, the characteristics of high-yield bonds are similar to the stocks’ such that the high-yield bonds are easily influenced by the change of economic environments, and the investigated results by Moody’s Invest Service during 1990-1991 also support that there is a high correlation between the economic environment performance and the default rate of HYB.

As to the dimension “characteristics of bonds” with a pretty high weight, it indicates that the experts consider the basic aspect of bonds’ characteristics pretty important on investments. The third importance is the dimension “financial factors”; since the information provided by this dimension is the past message without time effect, and the result shows that the experts consider this dimension a least impact on investments. About the exclusion of the dimension “nonfinancial factors”, it is presumed that there are lots of disagreements among experts’ opinions on the importance of this dimension.

2) Comparison of Criteria or Subcriteria within Individual Dimensions

1. Analysis on the Characteristics of Bonds

The results indicate that the importance of individual subcriteria within this dimension in descending order are “bonds callability” of 0.1385, “bonds liquidity” of 0.1118, and “change in credit rating” of 0.1017. There is a greatest importance on the subcriteria “bonds callability”, and it means that the greatest impact on HYB investment is callability.
According to our analysis, since there is a high default risk for high-yield bonds, the issuers’ callability should be stressed when the investors evaluate the HYB selection.

2. Analysis on the Financial Factors
Among five subcriteria within this dimension, their importance in descending order are “solvency” of 0.0776, “cash flow” of 0.0676, “financial structure” of 0.0440, “profitability” of 0.0312, and “growth” of 0.0231. There is a greatest importance on the subcriteria “solvency”, and it is sensitive to the events such as increase in debt or shortage of current capital. That will lead to the default, for example, no payment of interest or principal. And the little difference of 0.01 between the weight of “solvency” and of “cash flow” suggests that cash flow is also very important.

(1) With respect to “solvency”, the importance of subordinated subcriteria in descending order are “quick ratio” of 0.0304, “interest expense rate” of 0.0251, and ”current ratio” of 0.0222. There is a greatest importance on the subcriteria “quick ratio”, and the “quick ratio” reflects the short-term solvency of a company. Moreover, the “interest expense rate” is also an indicator of a company’s solvency.

(2) With respect to “profitability”, the importance of subordinated subcriteria in descending order are “pre-tax profit margin” of 0.0144, “return on assets” of 0.0087, and “net profit margin” of 0.0081. There is a greatest importance on the subcriteria “pre-tax profit margin”.

(3) With respect to “financial structure”, the importance of subordinated subcriteria in descending order are “debt ratio” of 0.0210, “current assets / total assets ratio” of 0.0159, and “retained earnings / total assets ratio” of 0.0071.

(4) With respect to “growth”, the most important factor is “assets growth” of 0.0231 with an important impact on evaluation of HYB selection.

(5) With respect to “cash flow”, the most important factor is “cash flow / total debts ratio” of 0.0676. Beaver [2] also pointed out that the cash flow / total debts ratio was the most significant variable to predict a company’s failure.

3. Analysis on the Economic Environmental Factors
The results indicate that the importance of subordinated subcriteria in descending order are “spreads versus Treasury” of 0.1512, “default rate index” of 0.1380, and “real interest rate change” of 0.1151.

3) Comprehensive Analysis
Besides, we make a whole analysis and comparison among seventeen lowest subcriteria. The results show that four subcriteria with more importance in descending order are “spreads versus Treasury” of 0.1512, “bonds callability” of 0.1385, “default rate index” of 0.1380, and “real interest rate change” of 0.1151. And four subcriteria with less importance in ascending order are “retained earnings / total assets ratio” of 0.0071, “net profit margin” of 0.0081, “return on assets” of 0.0087, and “pre-tax profit margin” of 0.0144.

IV. Conclusions
The purpose of our study is to provide an evaluation model of high-yield bonds selection built by the key criteria in the environment full of complexity and variation. The results indicate that there are different weights among individual dimensions or criteria and subcriteria rather than equivalent weights. And the importance among dimensions and the importance of subcriteria within individual dimensions are as follows.

1. The relative importance of evaluation dimensions in descending order are “economic environmental factors”, “characteristics of bonds”, and “financial factors”.

2. Within the dimension “characteristics of bonds”, the importance of subordinated subcriteria in descending order are “bonds callability”, “bonds liquidity”, and “change in credit rating”.

3. Within the dimension “financial factors”, the importance of subordinated subcriteria in descending order are “solvency”, “cash flow”, “financial structure”, “profitability”, and “growth”.

(1) With respect to “solvency”, the importance of subordinated subcriteria in descending order are “quick ratio”, “interest expense rate”, and ”current ratio”.

(2) With respect to “profitability”, the importance of subordinated subcriteria in descending order are “pre-tax profit margin”, “return on assets”, and “net profit margin”.

(3) With respect to “financial structure”, the importance of subordinated subcriteria in descending order are “debt ratio”, “current assets / total assets ratio”, and “retained earnings / total assets ratio”.

(4) With respect to “growth”, the most important factor is “assets growth”.

(5) With respect to “cash flow”, the most important factor is “cash flow / total debts ratio”.

4. Within the dimension “economic environmental factors”, the importance of subordinated subcriteria in descending order are “spreads versus Treasury”, “default rate index”, and “real interest rate change”.

5. Obtained from comprehensive analysis, three evaluation criteria with most importance are “spreads versus Treasury”, “bonds callability”, and “default rate index”.

Reference


